

DIGITAL CONNECTION

BY DON ROTOLO,* N2IRZ

A Basic Digital Oscilloscope

“The real strength of an oscilloscope is its ability to measure voltages over time”

Several months ago, a friend bought me a basic digital oscilloscope through Amazon, with the intent of using it in the TARPEN (Terrestrial Amateur Radio Packet Network) to monitor network audio. Little did I know I was being dragged into controversy.

Let's back up a moment: This month, we'll be taking a look at some oscilloscope basics, along with some info on an inexpensive and basic digital oscilloscope that many TARPEN builders are using to monitor their node's audio. While many hams are well-versed in oscilloscopes, using them in their work for example, I find that just as many hams really don't know much about them and are even intimidated by such a complicated piece of test equipment. I hope to explain the basics of what they are, how they work, how to use one, and how to recognize when you need one.

Oscilloscopes 101

Let's start with what an oscilloscope (pronounced “uh-SILL-uh-scope”) is, and what it can do for you (Photo A). Nearly everyone is familiar with a voltmeter, which can measure and display the voltage between two points in a circuit. Being able to “see” the voltage in a circuit is helpful, particularly when troubleshooting. But a problem with any voltmeter, from the free (with a coupon at Harbor Freight Tools) to the \$1,000+ lab-grade version, is that it can't show how the voltage is varying over short time periods. Indeed, my \$200 Fluke digital multimeter isn't fast enough to keep up with the turn signals in my car: A signal changing about once a second is just a little too fast, and I really have no way to measure the exact timing of that signal, either.

An oscilloscope is simply a voltmeter that displays the signal voltage as a horizontal line that moves up and down on a scale, instead of as digits or as a nee-



Photo A. My trusty Tektronix 465B oscilloscope. Purchased for \$200 at a hamfest, this is considered by many to be the Mercedes-Benz of analog oscilloscopes: Built like a tank, reliable as the sunrise, with excellent accuracy. In 1980, when it was introduced, it went for \$2,600 without options, about half the price of a Ford Escort (also without options).

dle pointer on a meter face. If you know that the display scale is, for example, 2 volts per division, it's easy to understand that a 12-volt signal would be displayed on the 6th scale division up from “zero.”

Seems like a complicated way to measure a voltage, but the real strength of an oscilloscope is its ability to measure voltages over time. In addition to the horizontal line showing voltage, the line also moves side-to-side to show the voltage at a precise point in time. That means if your voltage changes from 0 volts to 12 volts and back to 0 volts every second, as my turn signal is doing, you can actually see the points where the voltage changes as vertical movements of the line. Because the oscilloscope has a calibrated time base, you can set the display to show something like one second per scale division, meaning that each voltage change will be exactly one scale division wide.

Let's wrap our heads around this better: First, know that an oscilloscope screen is like a piece of graph paper, usually 8 divisions tall and 10 divisions wide. If my turn signal varies from 0 to 12 volts and then back to zero every second, and we have the oscilloscope set to display 2 volts per division tall and 1 second per division wide, we will see on the display a horizontal line that jumps from 0 to 6 divisions, and then back to 0 on the vertical (voltage) scale, once every horizontal (time) division. Photo B shows how this will look on the oscilloscope's screen.

Volts, Seconds, and Trigger

On any oscilloscope, there are three important settings: Voltage scale, Time (horizontal) scale, and Trigger. The voltage scale, in volts per division, sets the number of volts each vertical division represents. My Tektronix 465B has a range from 5 mV to 5 volts per divi-

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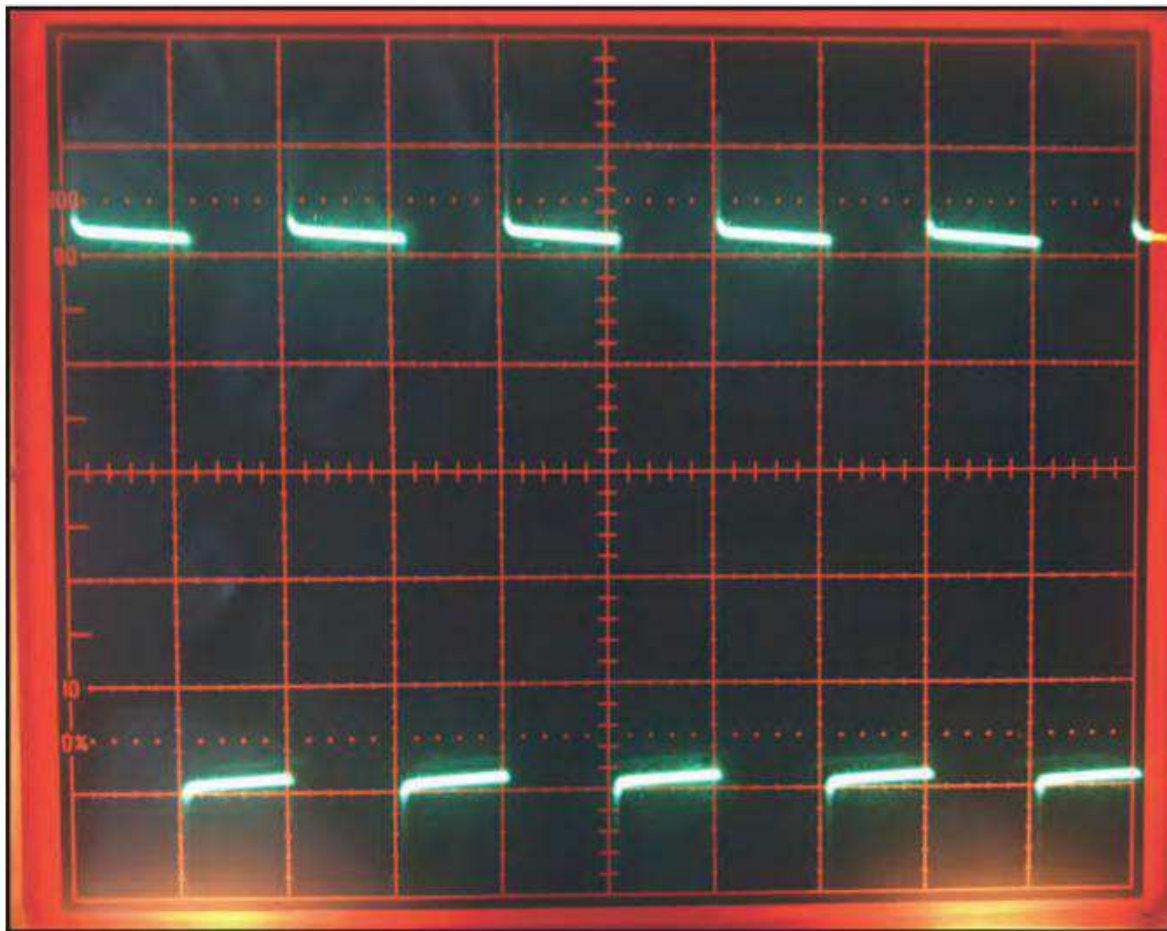


Photo B. This is what my car's turn signal voltage looks like at the bulb, as shown on an oscilloscope screen. It jumps between 0 and 12 volts and back to zero about every second. The oscilloscope is set to display 2 volts per division, and the time scale is 0.5 second per division. The glow at the bottom is from the screen illumination bulbs.

sion. The time scale sets the time represented by each vertical division, for example 0.02 μ Sec to 0.5 Sec per division. Note that the times are generally very small, since a scale of one or more seconds per division is not particularly useful.

Trigger is a whole different thing. When you are looking at signals that vary with time — basically why you'd be using an oscilloscope in the first place — you want the display to stand still long enough for you to look at and interpret what it is showing.

The Basics

When oscilloscopes were first developed, they used cathode ray tubes (CRTs) as displays, just like an older TV, before the flat-screen type. These work by projecting a stream of electrons (called an electron beam) toward the front of the CRT. The front inner surface of the CRT is covered in a phosphorescent material that glows when struck by an electron. The electron beam is steered across the face of the CRT by electromagnetic coils, which can bend the beam side to side and up and down. This moving beam created a glow on

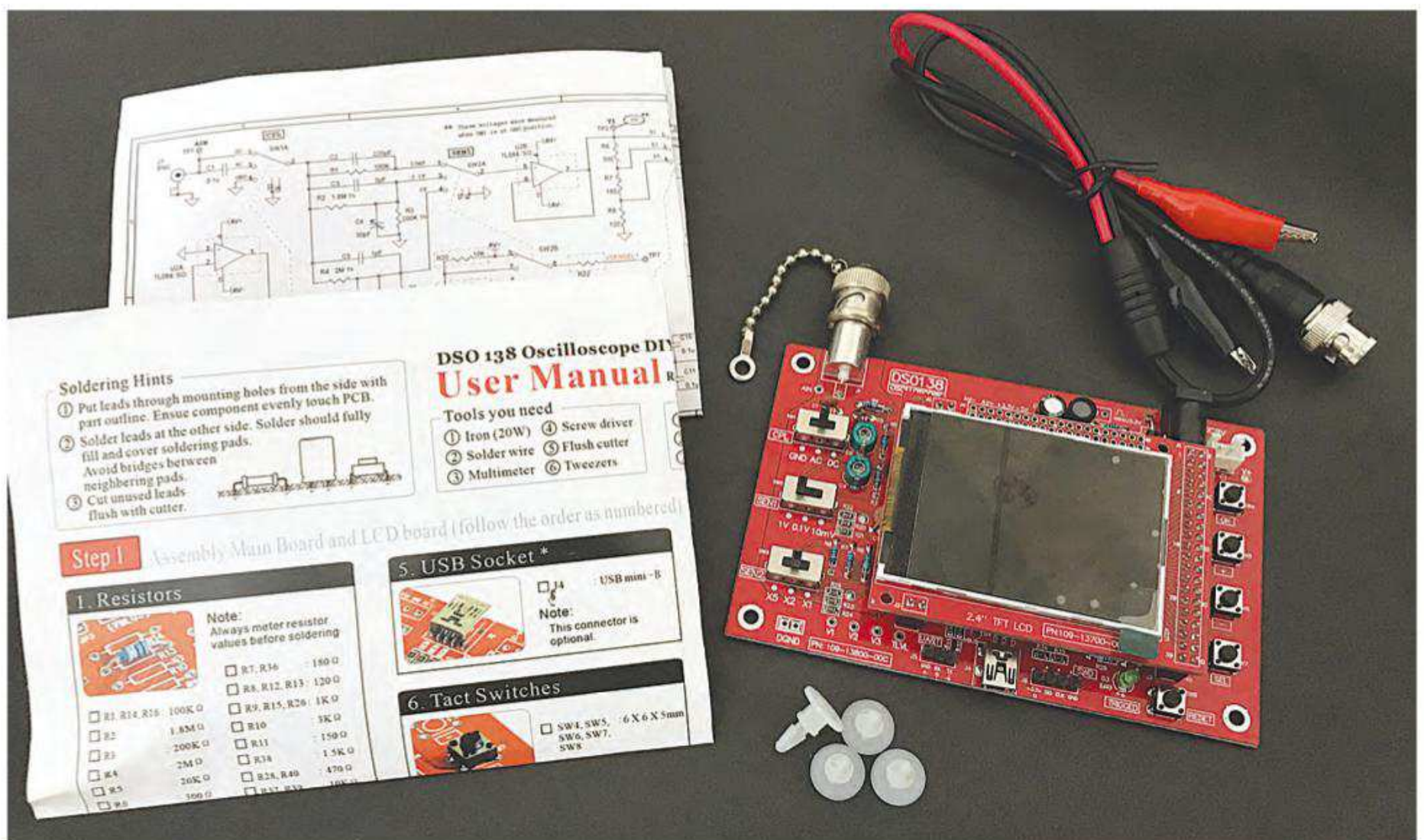


Photo C. The counterfeit DSO138 oscilloscope purchased on Amazon. This training scope, sold by JYE Tech, is widely counterfeited. The genuine article comes as a kit for about \$30, while fully assembled knockoffs go for about the same. Don't be fooled by the term "welded;" their understanding of English isn't perfect, and they don't always mean "assembled."

the CRT screen, called a trace. The trace moved around in a regular pattern in proportion to the input voltage (according to the voltage scale) and the time scale.

Unlike a CRT television screen trace, which actually was scanned across the entire front face of the TV screen and varied in brightness (producing an image), an oscilloscope trace was only scanned on the time scale (side to side) in a single line, moving up and down in response to the voltage input. The CRT surface only glowed for a fraction of a second for each trace, so the trace has to be repeated several dozen (or more) times each second for the line it produced to be visible to the eye.

Today, in the flat-screen age, we don't use electron beams any more, but the principles remain the same regardless of the display technology.

Keeping Signals Still

Triggering was used so that the oscilloscope trace would start at the same point in the signal's voltage pattern. Without triggering, you'd see only a mash-up of traces, all jumbled and overlapping each other. When triggered, the trace starts at the same point in the signal's pattern each time, so the line produced would appear to stand still and be easy to read.

Triggers can work on several types of signal characteristics, but most often you set a specific voltage level, at either the rising or falling slope, and the display is easily stabilized. While the details of triggering are beyond the scope of this column, it is important to understand that it stabilizes the oscilloscope display. In some cases, it isn't even necessary for the display to be stable, since useful information can be found even from an untriggered display, while in other cases (such as a non-repeating audio signal) triggering doesn't stabilize the display because it is changing somewhat randomly.

Using an oscilloscope is both easy and difficult at the same time. To get a basic signal to display, you just connect the

oscilloscope's probe to it, then fiddle with the time and voltage scale until you see a useful display. But even highly experienced users can get befuddled by a signal at times, where it refuses to trigger or sometimes even display at all. I can't make you an expert, but there are a lot of online resources where you can get started, and with just a little experience and play you'll see this is almost as easy as using a voltmeter.

What is it Good For?

When do you need an oscilloscope? While some people can brag that they can completely replace their multimeter with an oscilloscope, really its best use is with signals that vary over time, usually on the order of hundreds to tens of thousands of times per second. My Tektronix 465B has a bandwidth of 100 MHz, so viewing the output waveform of a 6-meter (50 MHz) transmitter (assuming proper connection) is

2018 ARRL/TAPR Digital Communications Conference

If you're at all interested in the state of the art in amateur digital communications, or just enjoy flocking together with similarly-minded technologists, I urge you to hop on a jet and attend the 2018 ARRL/TAPR Digital Communications Conference, at the Sheraton Albuquerque Airport Hotel in Albuquerque, New Mexico on September 14-16, 2018. This is the digital amateur radio world's 37th annual get-together, where all the latest and greatest ideas come together. Presentations are given Friday and Saturday at all levels, from basic introductory to over-my-head expert advanced, and the informal discussions at the bar, at the social, and at the banquet can go well into the evening. Sundays are reserved for in-depth seminars on various topics. Visit www.tapr.org/dcc.html for details as they are posted.

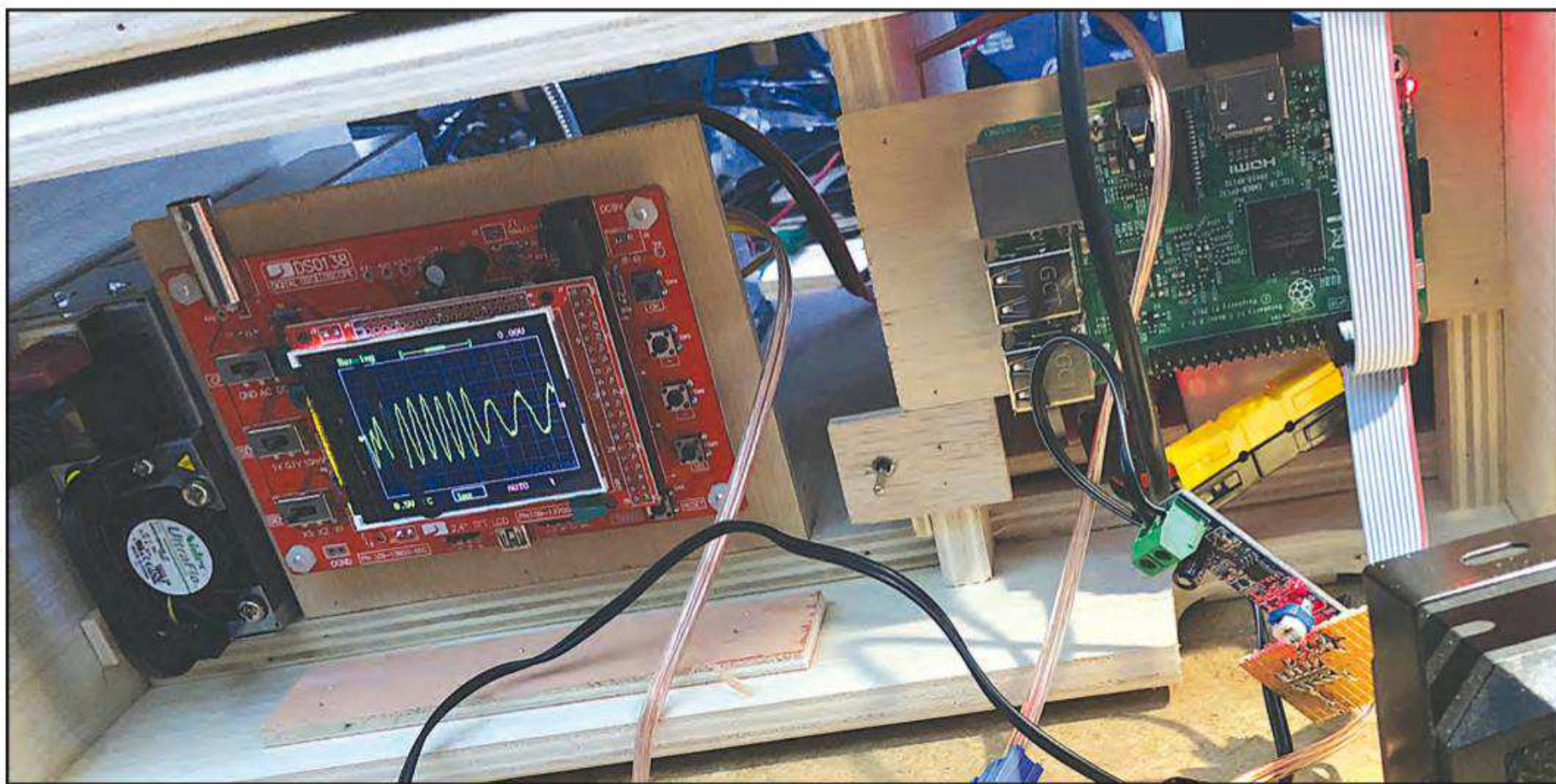


Photo D. A DSO138 oscilloscope installed in a TARP node to monitor node audio signals. The 'scope is generally installed in the "base" box with the Raspberry Pi (top right) and node power supply (center left). A switch on each TNC-Pi allows RX audio to be routed to the oscilloscope for display. The LCD display uses little power, so it can be left on indefinitely. (Courtesy of Tadd Torborg, KA2DEW)

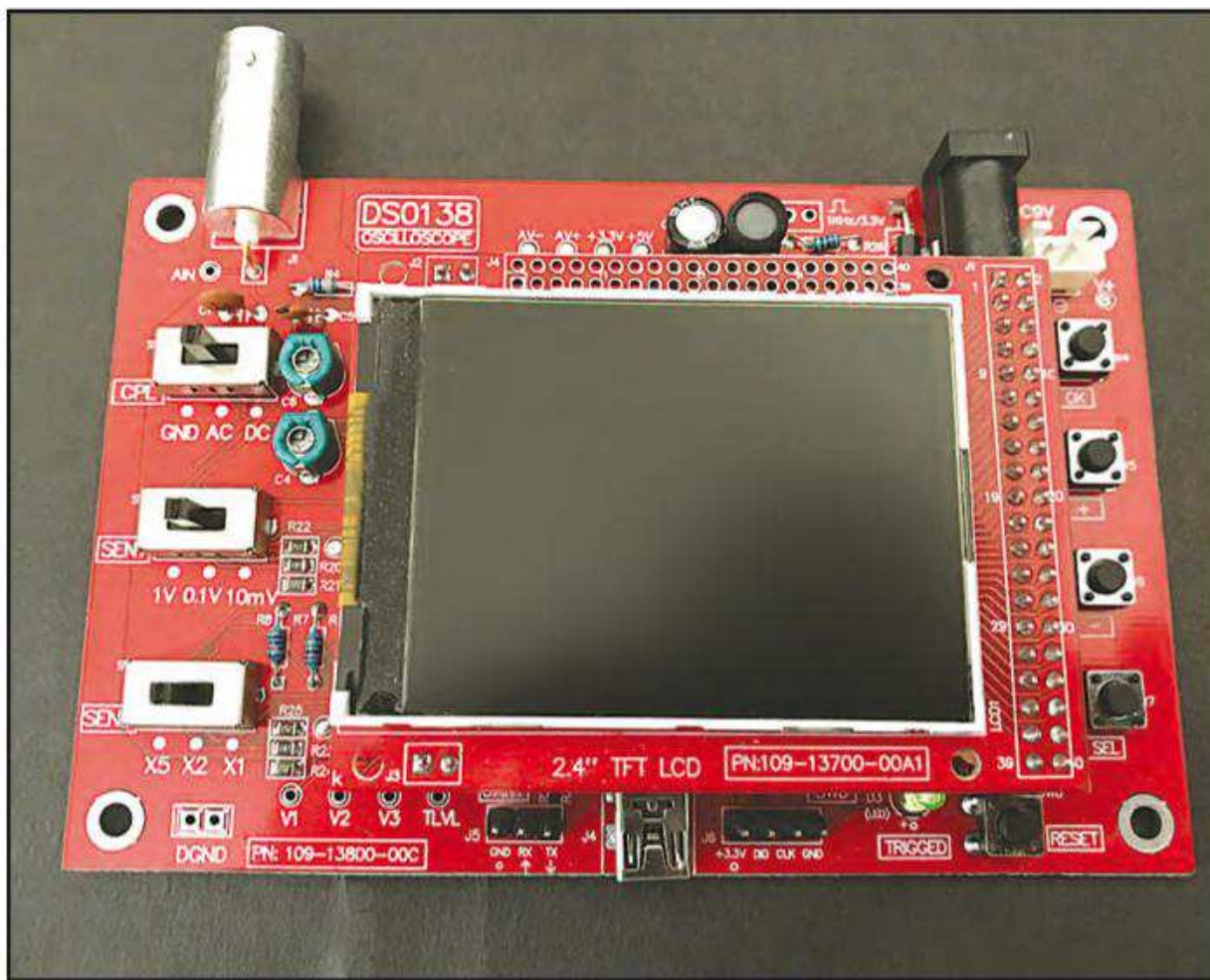


Photo E. The DSO138 showing some of the controls. At center left is the voltage scale setting. The time scale and trigger settings are set using the on-screen menu, controlled by the four pushbuttons at the right. The trigger level defaults to automatic, fine for most work, but can be manually set if necessary. The LED at lower right indicates when the trigger is active.

not an problem. The 465B was a low-priced oscilloscope: In 1980 a Tektronix 7834 with two 7A24 plug-ins and a 7B92A time base would set you back almost \$15,000 (without options), and that wasn't even the top end. Modern digital oscilloscopes can have bandwidths exceeding 1 GHz.

So, any time you want a graphical representation of an electrical signal, use an oscilloscope. When subtle differences in the shape of a waveform could be important, use an oscilloscope. If you want to impress visitors with space-age coolness, use an oscilloscope. Time characteristics of a signal are easily measured with great accuracy, while voltages (particularly at low frequencies) are not as accurate as with a voltmeter. Some waveforms can fool a voltmeter, so an oscilloscope might be the only accurate choice.

There are also some advanced features of most oscilloscopes, which I won't discuss much, that allow you to vary the electron beam's brightness, or to use a second voltage signal instead of the time base to move the trace side to side. You could, in theory, use an oscilloscope to display an analog television signal, or to compare the phase of two signals to each other graphically.

Another good use is to monitor radio audio signals, checking for distortion, signal level, or even that the signal is actually still there. As I mentioned at the beginning, TARPEN builders <<http://tarpen.net>> use a very inexpensive solid-state oscilloscope to monitor their node's audio. If a receiver isn't working, or the received audio is distorted, weak, or there is interference, an oscilloscope can help pinpoint the problem. While the human ear is also good at this, the receiver is normally tied directly into the TNC, so with a simple audio amplifier and an oscilloscope, you can selectively monitor the node stack to help find any problems.

DSO138

In a cost-sensitive application, you use the least expensive product that meets your needs. The DSO138 oscilloscope kit (Photos C, D, and E), designed by JYE Tech Ltd. in Guangxi, China <<http://jyetechnology.com>>, is widely available for about \$30. Fully-assembled counterfeits are available as low as \$15. JYE Tech does not sell them fully assembled, but some companies do assemble them for sale.

The DSO138 is sold primarily as a learning tool. As a laboratory instru-

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ment, it leaves a little to be desired. You can compare it to those free-with-coupon digital multimeters you can get at Harbor Freight Tools: Fine for most basic work, and excellent for learning, but cannot be compared to lab-grade instruments costing even as little as ten times as much.

And the controversy? The counterfeits: they are arguably illegal, since they use JYE Tech's design and firmware without any compensation. The one I purchased from Amazon is clearly not genuine, but the company selling it offers an 18-month warranty, so I presume it isn't junk. Copyright and patent laws in China are not the same as those we are familiar with here in North America, so I can't even pretend that I can determine if these are really illegal or not, but morally I can decide to use it or not. While certainly not a significant controversy like encryption on amateur radio, we each need to make that decision ourselves: I'm advocating buying the real thing and not a fake.

Talk to Me

I often wonder, am I writing about things you want to read? Drop me a line and let me know.

— Until next time, 73 de N2IRZ